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Threat Model for Environmental Sensing and Terrain Reasoning

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Threat Model for Environmental Sensing and Terrain Reasoning

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Agenda

- **Background.**
- **Combat M&S Issues & Needs.**
- **Threat Model Overview.**
- **Related Work.**
  - US Army's COMBAT XXI.
  - ONR's BASE-IT prototype.
- **COMBAT XXI & BASE-IT Comparison.**
- **Summary.**

COMBAT XXI: Combined-Arms Analysis Tool for 21st Century
BASE-IT: Behavioral Analysis and Synthesis for Intelligent Training
ONR: Office of Naval Research

Background

- **Current operations require that military forces be able to construct and protect a 300-person combat outpost or patrol base with integrated sensing and defense capabilities.**
- **The Deployable Force Protection (DFP) Technology Focus Team (TFT) identifies technology enabled-capabilities to meet force protection needs for forces operating remotely in small bases.**
  - Integrated, lightweight protection technologies.
  - Line-of-sight and non-line-of-sight detection.
  - Organic active and passive defense.
  - Robust and resilient systems.
- **The TRADOC Analysis Center (TRAC) in partnership with NPS and the MOVES Institute support to DFP TFT:**
  - Gap analysis to assess and prioritize gaps in current force protection capabilities.
  - M&S to determine the operational impact of force protection capabilities.

Combat M&S Issues & Needs

- **Representation of cognition in most combat M&S has lagged behind current technology and acquisition trends.**
  - Current combat models and simulations have limited ability to model entity interactions with the battle space environment.
- **Current demands on combat M&S and the need to represent DFP capabilities require intelligent behaviors for:**
  - Environmental sensing.
  - Terrain reasoning.
  - Intelligent target search.
  - Knowledge management.
  - Other decision-making behaviors.
- **There is a stated need and interest from the M&S community for a threat model capability.**

Threat Model Overview

- **Leverages several detailed models of individual combatant behaviors developed by TRAC and MOVES.**
- **A prototype model that augments the simulation of interactions of entities with the battle space.**
- **Creates environmental sensing knowledge sets to support terrain reasoning to include dynamic situations.**
  - Target search, route selection, emplacement of tactical positions.
  - Locating nearby cover, planning concealed paths, moving in formation, selection of movement technique, assessment of enemy positions.
- **Components:**
  - Terrain analysis program.
  - Model of invisible threats.
  - Search and movement model.

Goal is to represent individuals and units that realistically search for threats, keep an updated model of likely threat positions, and dynamically replan their movements.

Threat Model Overview

Terrain Analysis Program

- **An offline program for entities in the simulation to take into account terrain in their planning, decisions, and actions.**
  - Terrain representation.
  - Functions to construct, query, and manipulate the terrain representation.
- **Leverage line of sight and computer vision-like techniques to characterize the terrain.**
  - Intervisibility between points.
  - Detection probability and time.
  - Cover affordance (including cover from particular threat directions).
  - Suitability of positions for distinct actions (sniping, ambush, etc.)
- **Utilize hierarchical navigational graphs to feed ACQUIRE-like target acquisition models in a scalable manner.**
  - Pre-computed visible surface area and contrast to background information.

Threat Model Overview

Model of Invisible Threats

- **A dynamic model of the distribution of perceived threat to improve behaviors for target search, planning, and maneuver.**
- **Threat probability model incorporating Bayesian statistical model.**
  - Accounts for the prior distribution of threat in the environment and the unit's observations of the environment.
- **Depends on pre-computed acquisition parameters from the terrain analysis module.**
- **Subjective to the entities in the simulation.**
  - Individual or group of combatants.
- **It accounts for the fact that threats can move.**

Threat Model Overview

Search and Movement Model

- **An integrated model search and movement behavior system for improved search, movement planning, and finding paths taking tactical information into account.**
- **Takes into account factors and doctrinal aspects of unit movement such as:**
  - Dynamic movement control (speed, direction, orientation).
  - Maintenance of proper dispersion.
  - Exploitation of cover and micro-terrain.
- **Relies on pre-computed intervisibility & acquisition parameters from the terrain analysis model and the model of unseen threats.**

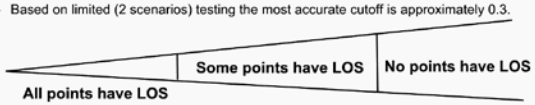
Related Work: COMBAT XXI

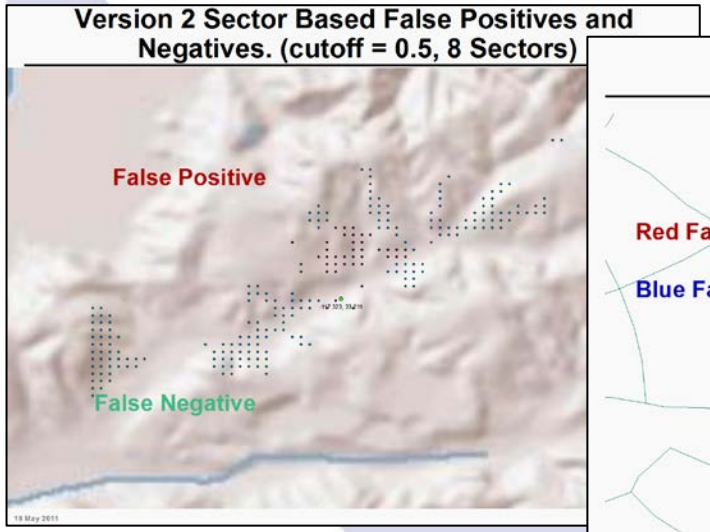
Pre-computed line of sight (LOS) methods:

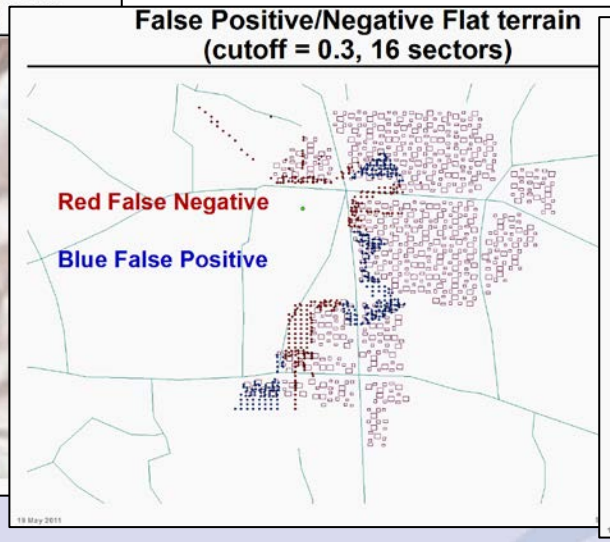
- **Point based.**
  - Coarse grid of nodes to approx. true LOS.
- **Sector based.**
  - Nodes are grouped by sector, for each node, defined by bearing and range bands.
  - If the node has LOS to any node in a sector, then it is assumed to have LOS to the sector.

Version 2 Sector Based Pre-calculated LOS

- Based on "Killzone's AI: Dynamic Procedural Combat Tactics"
- For each node, the following data are calculated for each sector.
  - A range that the node has LOS to all nodes.
  - A range beyond which the node has no LOS.
  - The proportion of the nodes in the middle that have LOS.
- At model runtime
  - The estimated LOS is true if the range to the node of interest is less than the "all LOS range".
  - False if the range is greater than the "no LOS range".
  - If the range is in the middle region
    - If "use actual in middle" is true, then the actual LOS is returned.
    - Otherwise, true is returned if the proportion of nodes with LOS is above a user specified value.
      - Based on limited (2 scenarios) testing the most accurate cutoff is approximately 0.3.







Pre-computed LOS Performance Comparison

- Camp Pendleton: 16.4 km², 50m node spacing, 3% covered with buildings. 7340 / 7994 nodes. (8 Sectors)

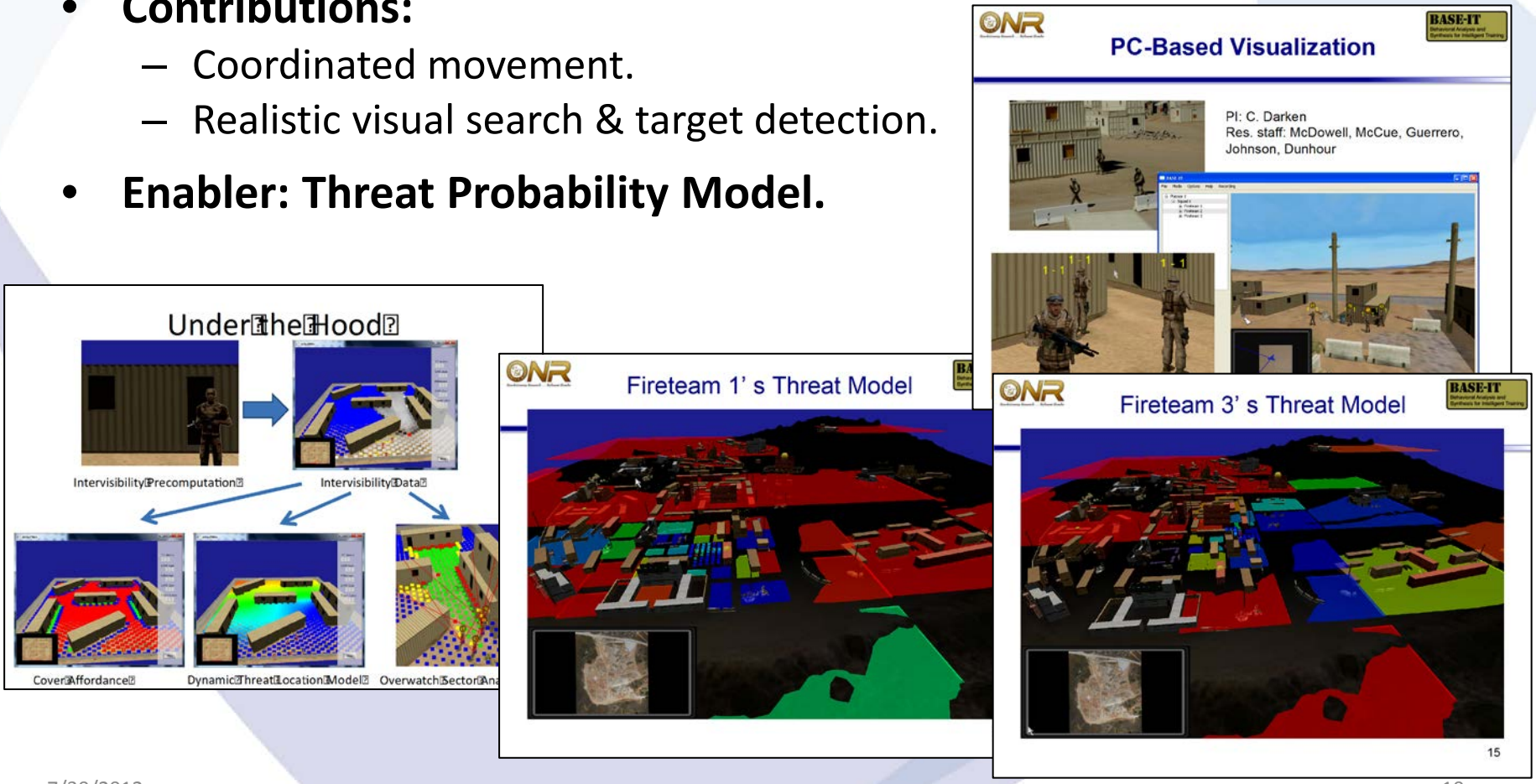
	Point Based	Sector Based 2 (0.3 cutoff)	Sector Based 2 (actual in middle)
False Positive	0.1%	3.9%	0.02%
False Negative	5.0%	6.0%	1.0%
Speed (over actual LOS)	35% faster	63% faster	51% faster
LOS file size	126M	4.5M	4.5M

- Fictitious Flat Terrain: 1.7 km², 20m node spacing, 40% covered with buildings. 7491 / 7999 nodes. (8 Sectors)

	Point Based	Sector Based 2 (0.3 cutoff)	Sector Based 2 (actual in middle)
False Positive	1.0%	2.7%	0.1%
False Negative	2.0%	5.3%	0.4%
Speed (over actual LOS)	25 times faster	24.5 times faster	3.5 times faster
LOS file size	141M	4.4M	4.4M

Related Work: BASE-IT (1 of 2)

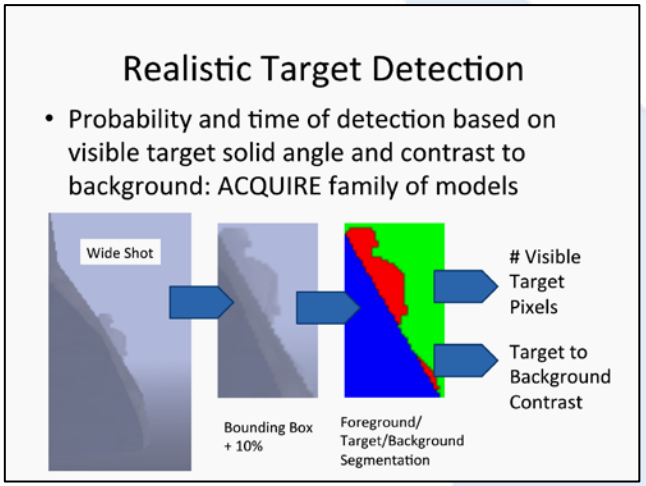
- **BASE-IT is a standalone US Marine Corps training application.**
  - Prototype tool with novel algorithms to simulate fireteam movement and visual scanning appropriate to urban environments.
- **Contributions:**
  - Coordinated movement.
  - Realistic visual search & target detection.
- **Enabler: Threat Probability Model.**

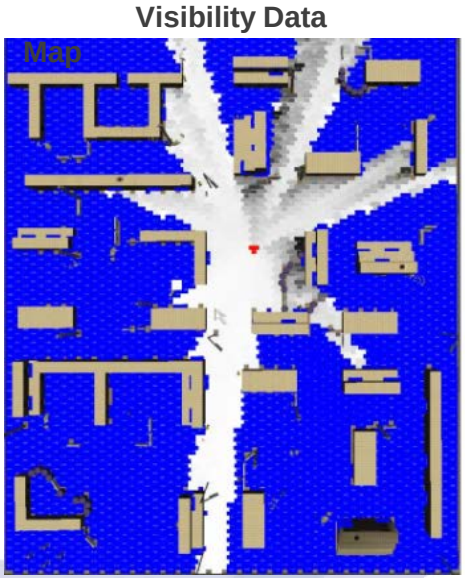


Related Work: BASE-IT (2 of 2)

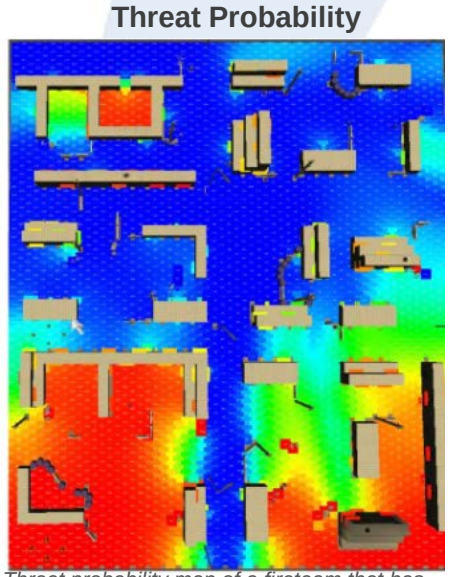
Threat Probability Model

- **Threat map: probability distribution providing a subjective estimate of the threat's location.**
- **Variant of ACQUIRE detection model based on pre-computed target size and contrast values.**
- **Dynamic hierarchical representation with fine detail near the observer, coarser far from observer.**
- **Improved visual search behavior prioritizing locations that are most likely to contain a threat.**





Pre-computed contrast values from a single red point (whiter is better).



Threat probability map of a fireteam that has explored most of the upper right region (hot colors represent high perceived threat values).

COMBAT XXI & BASE-IT Comparison

- **Model Infrastructure.**
- **Terrain representation.**
- **Sensing.**
- **Detection.**
- **Visual Search.**
- **Movement.**

Summary

- **Summary.**
  - There is a need to represent more realistic intelligent behaviors in combat M&S with enough detail to estimate the operational effectiveness of DFP capabilities.
  - A threat model capability that takes the battle space and threat into account to improve the representation of behaviors for target search, planning, and maneuver would increase realism in combat M&S.

- **Way Ahead.**
  - Exploit the specific advantages of the techniques and algorithms developed for COMBAT XXI & BASE-IT to improving the overall representation of cognition.
  - Continue assessment of requirements, development, and implementation of the threat model prototype capability.

Questions?

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